FIGHTING A FIRE IN NO. 59 MINE PEABODY COAL CO., SPRINGFIELD SANGAMON COUNTY, ILL.

BY J. A. O'CONNOR, J. S. MALESKY, AND T. C. HIGGINS

* * * * * * * * * **Information Circular 7564**

UNITED STATES DEPARTMENT OF THE INTERIOR
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CONTENTS

Page
Introduction.. 2
Acknowledgment...................................... 3
General information................................. 3
Mining methods, conditions, and equipment........... 3
Story of fire....................................... 6
Conditions immediately preceding introduction of carbon dioxide.... 10
Introduction of carbon dioxide...................... 12
Recovering the fire area............................ 13
Investigation of cause of fire...................... 18
Conclusions... 19

ILLUSTRATIONS

Fig. — Follows page
1. Map of No. 59 mine.............................. 6
2. Map of fire area................................ 6
3. Details of 13 south (Bissell) shaft bottom...... 8

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INTRODUCTION

This circular contains the story of a stubborn mine fire of electrical origin that started on the main haulage road of No. 59 mine of the Peabody Coal Co. and illustrates that sometimes serious fires can be fought by direct attack. The story also points out that the cost of such procedure can be extremely high, and it is better, therefore, to minimize the possibility of a fire of electrical origin by suitable over-current and line-fault protection. The lives of 163 men were saved by utilizing a recently sunk air shaft near active workings as an escapeway. These men could not have reached the older openings. Also described are the rescue of 75 additional men through another air shaft, sealing of the fire, attempted extinguishment with carbon dioxide, and the difficulties of fighting the fire and recovering the mine.

A fire occurred shortly before 12 o'clock noon, August 15, 1949, in the No. 59 mine, Peabody Coal Co., Springfield, Ill. All 257 men underground escaped to the surface. One group of 75 men was delayed from escaping for several hours after the alarm was given because smoke and fire gases were circulating in a main return airway, which intervened between their working section and one air shaft, and also in the stairway compartment of the shaft. After being supplied with universal-type gas masks, or self-rescuers, these men were conducted from the mine by members of a State mine-rescue team and other mine employees. Six mine officials were hospitalized because of exposure to carbon monoxide during fire-fighting activities; all were discharged a few days afterward. Later, while doing work incident to fighting the fire, two men were killed, and several were injured by falls of roof and rib.

The fire broke out after a collision of a loaded trip with four empty mine cars on the main east haulage entry. The mine cars were jammed against the trolley wire causing a sustained electric arc that ignited the wooden mine cars and the fire spread to the timbers and coal.

T. C. Higgins, Federal coal-mine inspector, headquartered in Springfield, Ill., notified James Westfield, Chief, Vincennes (Ind.) Branch, Region VIII, Bureau of Mines, of the fire and its seriousness, and that up to 4:30 p.m. of that day approximately 200 men had not escaped to the surface. Westfield accompanied by F. J. Smith arrived at the mine at 9 p.m. Additional men were requested from the Bureau's Vincennes office and F. J. Gallagher, J. S. Malesky, and James A. McCune responded and arrived at the mine at 9:15 a.m., August 16.

The fire was fought by direct means with rock dust and by loading burning material into mine cars until August 18, after which the management decided to seal the fire area. Both main east entries were sealed to enclose the fire, and 21 tons of liquid carbon dioxide was vaporized and admitted to the sealed area. During sealing, and until the mine resumed operation on November 14, 1949, one or more of the following Bureau employees maintained close contact with the operations: James Westfield, J. A. O'Connor, J. S. Malesky, T. C. Higgins, and C. M. Dovidas.

ACKNOWLEDGMENT

It is impossible to list by name the many individuals to whom the authors are indebted for courtesy and cooperation. As a means of expressing their appreciation to all who were helpful, the authors thank J. D. Kelly on behalf of all the men, officials, and office staff of Mine 59; A. J. Colquhoun on behalf of all the division officials; D. F. McElhattan, safety engineer; and Walter Eadie, on behalf of the staff of the Illinois Department of Mines and Minerals.

GENERAL INFORMATION

The No. 59 mine is about 4 miles northeast of the center of Springfield and is served by the Springfield Terminal Railroad. Of the 401 men employed, 315 worked underground. The average daily production was 3,000 tons of coal.

The mine was opened by four shafts each 240 feet deep. The main shaft (the hoisting, man, and material shaft), was also an upcast air shaft. The original intake-air shaft was 300 feet northwest of the main shaft; it was equipped with a blowing fan, used when desired for auxiliary ventilation of the main bottom area, and had a stairway compartment. The 13 south (Bissell) shaft, 8,200 feet east of the main shaft had two compartments; one was downcast, and the other was a stairway compartment, normally upcast. The 37 south (Wentworth) air shaft, 15,400 feet east of the main shaft and 7,200 feet east of the 13 south shaft, was a 5-foot circular, single-compartment, downcast shaft. It was equipped with a light headframe and a 3-man circular cage for emergency use but was not equipped with a permanent hoist. In addition to the four shafts, No. 59 mine was connected on the east to the abandoned Riverton No. 52 mine, and its two shafts, which, although not accessible for travel, were utilized to some extent as outlets for return air from No. 59 mine.

Mining operations are conducted in the Illinois No. 5 coal bed, which in this mine averages 66 inches in thickness and is undulating. The immediate roof is shale, above which is a hard but relatively thin cap rock at some places; the main roof is generally soapstone. Frequent "horsebacks" occur in the roof; these cavities are either roughly cylindrical or trenchlike and are filled with unconsolidated, shaly material foreign to the rather massive country rock. Their dimensions vary widely.

MINING METHODS, CONDITIONS, AND EQUIPMENT

A panel room-and-pillar system of mining was followed, but pillars were not extracted. Main entries, cross entries, and panel entries were originally driven in pairs 12 feet wide on 36-foot centers. Rooms were driven 24 feet wide with crosscuts 60 feet apart. Panel entries were turned either from main (east-west) or from cross (north-south) entries. Barrier pillars between the entry and the first room in a panel were usually 40 feet wide. These conditions prevailed in the area where the fire occurred. In more recent workings the same general dimensions were maintained, but entries, including room-panel entries, were driven in sets of four.

The main entries were timbered rather extensively throughout the greater part of their length. As conditions required, timbering consisted of props with cap pieces or wooden cross bars, rails of different weights, and I-beams set on wooden legs with or without cribbing.

Ventilation was accomplished by means of two electrically driven centrifugal fans installed underground, operated blowing and not reversible. The fan at the foot of the 13 south (Bissell) shaft provided a separate air circuit for the 13 north section; this fan drew intake air down one compartment of the shaft, forced the air through an overcast across the main east haulage entry, thence into the 14 north entry to several active panels, from which it returned through 13 north entry to the main east haulage entry, which is the principal return air course for the mine.

The 37 south (Wentworth) fan drew intake air down the single-compartment shaft and forced it through an overcast across the main east haulage entry, thence into 25-26 north and 37-38 south entries to active workings, from which the air returned to the main east haulage entry. The 25-26 north and 37-38 south entries were turned from the main east entries in direct line with each other. A split of air ventilated the active workings of the 10 east off 37 south, and part of the air reached the surface through the shafts of the abandoned Riverton No. 52 mine lying east of the No. 59 mine.

From the common intersection of 25 north and 37 south entries with the main east entries, the main body of return air from the east workings moved westward through the main east entries to the 13 north entries, where it converged with the return air from the 13 north section; part of the combined volumes of return air then passed up the stairway compartment of the nearby 13 south (Bissell) shaft, and part continued westward through the main east entries to the main hoisting shaft. When the fire occurred in the main east haulage entry at 17 south, which is between 13 north and 37 south, the volume of return air moving westward through the fire area was probably 30,000 to 40,000 cubic feet per minute, the usual volume in that part of the mine. As the back main east entry, (the parallel entry of the pair,) was obstructed badly with fallen material and blocked at 14 north by a stopping, it is likely that the greater part of the air volume was passing through the haulage entry.

From the foregoing, it is obvious that no means of escape in intake air was available to the men in the mine when the fire occurred, except those in the vicinity of the main shaft bottom; these men could have used the original air shaft with its separate forcing fan had such action been necessary. The 37 south (Wentworth) shaft was ventilated by intake air and could be reached by those in the east workings, but it was not equipped with a permanent hoist. The main shaft and the stairway compartment of the 13 south (Bissell) shaft were ventilated by return air.

This mine has not been classified by the Illinois Department of Mines and Minerals as a gassy mine, but air samples collected during Federal inspections contained more than 0.25 percent methane, and gas has been detected with a flame safety lamp. Ten air samples were collected during a Federal inspection completed August 4, 1949, and the highest methane content of any sample, including face samples, was 0.17 percent. The highest methane content of any sample collected from the fire area was 1.2 percent, and one sample collected at the Riverton No. 52 abandoned main shaft, representing return air coursed through old workings, contained 0.99 percent methane. The samples from the fire area and from the Riverton shaft represent slowly moving air currents that could not be measured. Suffice it to say that, fortunately, methane was of negligible importance in combating this fire.

Trip lights were used on the rear of trips pulled, but at the passing tracks, which were in entries parallel to the main line, one motorman could not see the light of the other trip unless by chance he was at or near the switch waiting for the other trip to pass. Because of the undulating nature of the floor and the many consequent local changes in grade, a motorman could not see his own trip light at many points.

The underground direct-current power system played an important part in the fire. Face and haulage equipment was supplied from the one general system, which consisted of four 300-kilowatt, 275-volt generators driven by 2,300-volt synchronous motors installed underground, and one 200-kilowatt, steam-driven generator installed near the top of the main shaft on the surface, in main east at 13 south, in 13 north, 25 north, and 37 south. The interval between the motor-generator sets ranged from 6,000 to 11,000 feet. All five generators were operated in parallel to equalize loads and were connected by means of 1,000,000 circular-mil positive and negative feeder lines, 6/0 trolley wire on the positive side of the circuit, and 90-pound unbonded rails on the negative side. Automatic circuit breakers were provided between each motor-generator set and the load; these were set at a maximum 1,800 amperes to permit 50-percent overload on a 300-kilowatt set. Manually operated disconnecting switches were installed in the trolley and feeder lines near each substation and branch junction to permit isolating various segments of the system, but automatic overcurrent circuit-breaker equipment was not provided for promptly isolating overloaded or line-faulted areas from the remainder of the system. Each instantaneous breaker would cut its set off the line if the fault occurred near enough to that particular set but would not clear the fault from the electrical system, and the other generators could continue to operate.

Three members of one State mine rescue team are employed at No. 59 mine. One of the rescue stations maintained by the Illinois Department of Mines and Minerals is at Springfield, and a fully equipped, modern mobile rescue unit is assigned to that station.

Water lines and hose were available on the surface and at the shaft bottom. Underground fire-fighting equipment consisted chiefly of rock dust; room-type distributors and one large track-mounted distributor were available. Supplies of rock dust were kept at many points in the mine, and rock dust and fire extinguishers were kept available at substations. Water-tank cars with pumps also were available.

So far as known, the only previous fires in this mine were those started when blasting with black blasting powder; such fires were extinguished without much difficulty.

STORY OF FIRE

At 11:45 a.m. on August 15, 1949, a locomotive hauling 29 loaded cars westward in the main east entry collided with four empty cars that had become uncoupled from an eastbound trip and were standing in a "swag." The impact derailed the empty cars, the locomotive, and several loaded cars, but the motorman was uninjured. The empty cars were thrown crosswise and upward and became entangled in the trolley wire. A short circuit was established through the metal frames of the cars from the trolley to the rails and the negative feeder; and the short circuit was maintained with power from both sides for a considerable period. The resultant arcing, or the heating of the car frames and power wires, or both, ignited the wooden car bodies and nearby timbers.

The collision occurred in the main east entry at its intersection with 17 south entry, which is 10,000 feet east of the main shaft, 2,000 feet east of the 13 north intersection, and 5,500 feet west of the "Y" intersection with 25 north and 37 south entries. Active face operations were in panels turned from the 13 north, 25 north, 37 south, and 10 east off 37 south entries. The nearest power-disconnecting switches and telephones were 2,000 feet west (at 13 north) and 1,000 feet east (at the No. 5 passing track). (See figs. 1 and 2.)

The motorman was unable to dislodge the wrecked cars because his locomotive had been derailed and he was unable to separate the trolley wire from the cars. Help was summoned, and soon men began to arrive from both west and east, including the mine superintendent and the mine manager. When the wire was cut on one side of the fire, power could still feed through the short circuit from the other side. The men working on the west side decided to cut off the power from that side, and a man went to 13 north, opened the trolley and the feeder switches, and, after the trolley wire had been cut near the fire, the trolley switch was closed to permit use of the locomotives. It was then discovered that the trolley wire was feeding power into the feeder cable through cross bonds and thus around the "gap" in the trolley wire and into the short circuit at the fire. The cross bonds were found and cut; consequently the three generators west of the fire could no longer feed through the short circuit. The 37 south breaker opened, cutting off the motor-generator set from the outby portion of the distribution system, but the 25 north generator still could feed the short circuit from the east until the lines on that side were cut. It is not known definitely which side was cleared first, nor how much time elapsed before power was cut off completely from the short circuit, but, from reports of the steps taken, it may have been as much as an hour after the wreck occurred.

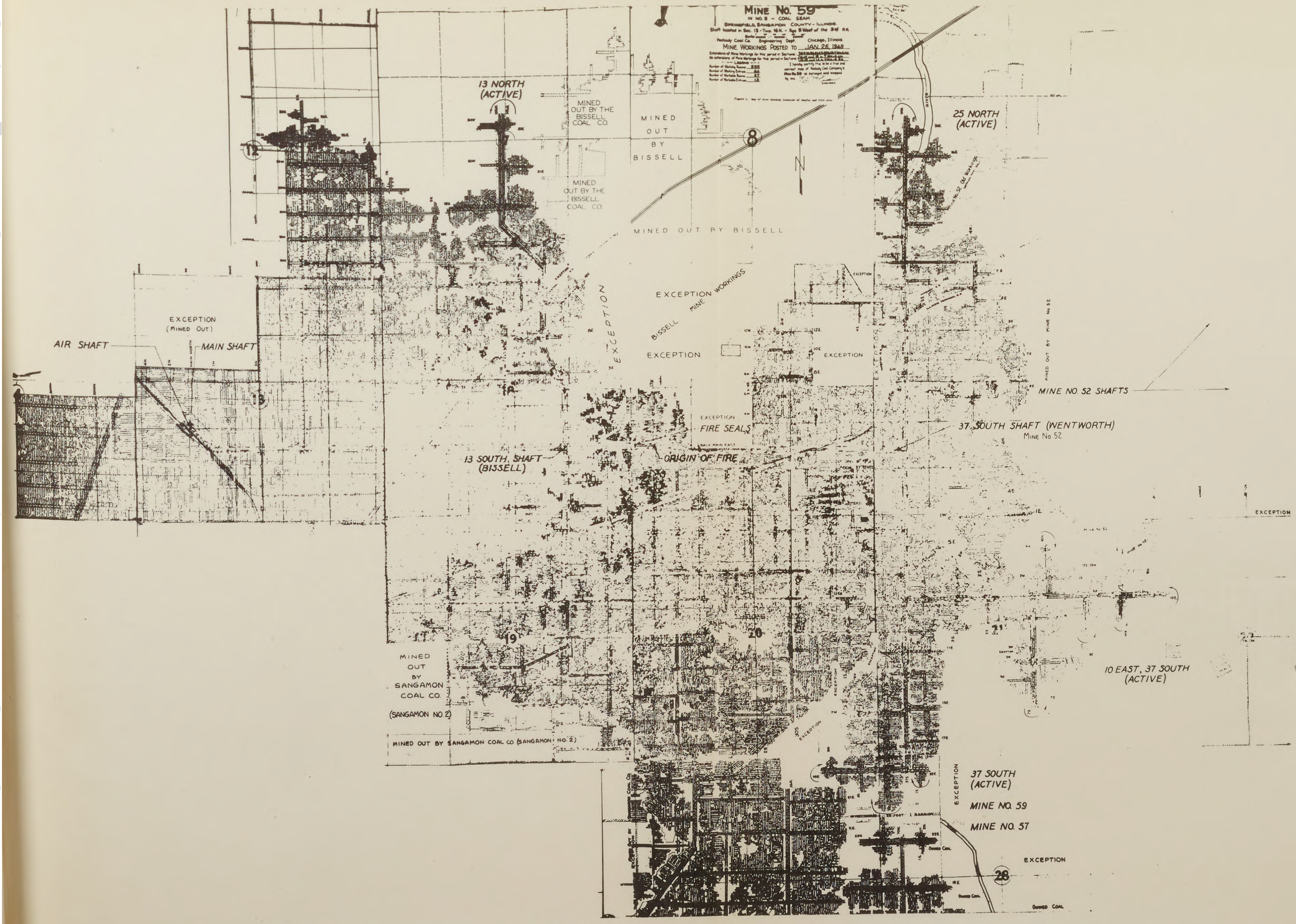
MINE No. 59
IN NO. 5 - COAL SEAM
SPRINGFIELD, SANGAMON COUNTY - ILLINOIS.
Shaft located in Sec. 13 - Twp. 16 N. - Rge. 5 West of the 3rd P.M.
Peabody Coal Co. Engineering Dept. Chicago, Illinois
MINE WORKINGS POSTED TO JAN. 26, 1949
Extensions of Mine Workings for this period in Sections
No extensions of Mine Workings for this period in Sections
LEGEND
Number of Working Rooms 255
Number of Working Entries 64
Number of Workable Rooms 27
Number of Workable Entries 12
I hereby certify this to be a true and correct map of Peabody Coal Company's Mine No. 59 as surveyed and mapped by me.
ENGINEER
13 NORTH (ACTIVE)
MINED OUT BY THE BISSELL COAL CO.
MINED OUT BY BISSELL
MINED OUT BY THE BISSELL COAL CO.
MINED OUT BY BISSELL
25 NORTH (ACTIVE)
N
12
8
EXCEPTION (MINED OUT)
AIR SHAFT
MAIN SHAFT
EXCEPTION
EXCEPTION BISSELL MINE WORKINGS
EXCEPTION
EXCEPTION
MINED OUT BY MINE No. 52
MINE NO. 52 SHAFTS
37 SOUTH SHAFT (WENTWORTH) Mine No 52
EXCEPTION FIRE SEALS
13 SOUTH, SHAFT (BISSELL)
ORIGIN OF FIRE
18
EXCEPTION
19
20
21
22
MINED OUT BY SANGAMON COAL CO. (SANGAMON NO. 2)
MINED OUT BY SANGAMON COAL CO. (SANGAMON NO. 2)
10 EAST, 37 SOUTH (ACTIVE)
EXCEPTION
37 SOUTH (ACTIVE)
MINE NO. 59
MINE NO. 57
EXCEPTION
28

Figure 1. - Map of mine No. 59.

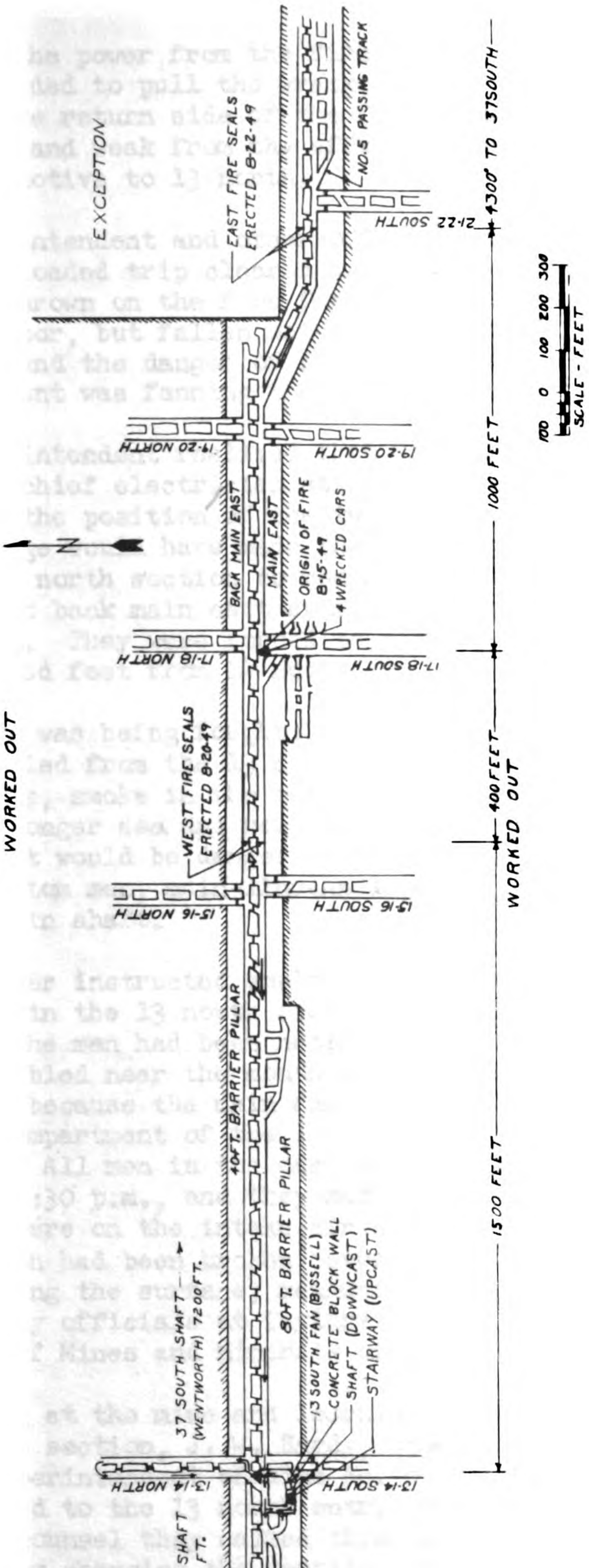

Figure 2. - Large-scale map of fire area.

After cutting the power from the fire on the west side, a mine official and several men decided to pull the wrecked empty cars from the fire area. These men were on the return side of the fire, and before they could do this they became so sick and weak from the effects of carbon monoxide that they retreated on a locomotive to 13 north.

When the superintendent and other officials reached the fire from the east, they had the loaded trip cleared away and started to apply rock dust. The rock dust was thrown on the fire for several hours by hand and by means of a large distributor, but fallen material made it difficult to reach the heart of the fire, and the danger of further falls was a hazard. Meanwhile, the strong air current was fanning the fire along the timber legs and lagging.

When the superintendent realized that the fire was not to be extinguished easily, he and the chief electrician attempted to reach the fan at 13 south in order to change the position of the two doors, one at each side of the stairway. The change would have made the stairway a downcast and would have permitted men in 13 north section to reach the surface. The two officials traveled through the back main east entry, which was passable but badly obstructed by falls. They were forced to give up and return after reaching a point a few hundred feet from 14 north.

While the fire was being fought, face operations had continued and coal was still being hauled from the 13 north working sections to the shaft bottom. After the third trip, smoke in the main east haulageway was do dense that the motormen could no longer see and were affected by carbon monoxide; they therefore decided that it would be dangerous to attempt another trip. Nineteen men employed as bottom men, main-line-haulage men, and repairmen left the mine through the main shaft.

The mine manager instructed employees west of the fire to relay orders to the face bosses in the 13 north sections to bring their men out. This was done, and all the men had been notified by 1:30 p.m. The face bosses and their men assembled near the mouth of 13 north entry, and it was decided not to go farther, because the main east entry, the crosscut to the shaft, and the stairway compartment of the 13 south (Bissell) shaft contained return air from the fire. All men in the east workings also had been notified to withdraw by about 1:30 p.m., and they made their way to the 37 south (Wentworth) shaft, where they were on the intake-air side of the fire. By that time the telephone connection had been broken between points east of the fire and points west of it, including the surface; meanwhile, the employees in the mine office had notified company officials at Taylorville, Ill., and Walter Eadie, director of the Department of Mines and Minerals of the State of Illinois.

After arriving at the mine and learning the situation with respect to the men in the 13 north section, J. W. Hardy, superintendent of mine No. 9, and M. J. Donnelly, superintendent of mine No. 8, descended the 13 south shaft stairway and crossed to the 13 north entry, where the men had assembled. By their actions and counsel they calmed those inclined to be panicky, and explained the plan for changing the ventilation by stopping the 37 south fan after all men at the 37 south shaft had been hoisted to the surface.

None of the officials or men in the 13 north section thought of entering the 13 north air course and crossing over the main east through the overcast to reach the 13 south shaft. Although a mistake had been made in not providing a door in the wing wall at the 13 south fan, the men could have traveled in intake air to the bottom of the shaft by knocking out a few blocks in the wing wall and opening the bypass door at the fan. (See fig. 3.) However, as such course of action apparently did not occur to anyone at the time, and as the danger was not imminent, good judgment was exercised in remaining in 13 north until after making arrangements that left no doubt that it was safe to proceed to the surface.

A power winch mounted on a motor truck was rigged to the 3-man emergency cage in the 37 south (Wentworth) shaft, but the task of hoisting the men from the east workings proceeded very slowly, being limited by the speed of the winch. The rope was then secured at a fixed point on the drum, after which hoisting and lowering of the cage proceeded more rapidly by tramming the truck back and forth across a field adjacent to the air shaft. In all, 163 men were removed from the mine through this shaft. Although the men in the east workings were in no immediate danger, a permanent hoist at this air shaft would have permitted the superintendent to reach the surface and rescue the men from the 13 north section more rapidly and with less anxiety for all concerned.

After his unsuccessful effort to reach the 13 south fan through the back main east entry, the superintendent went to the 37 south shaft to learn what progress was being made in evacuating the men there. Finding the emergency cage in operation, he went to the surface, and thence to the 13 south shaft to learn of the progress there. Being informed that none of the men from 13 north had escaped and that the doors at the shaft bottom had not been changed, he ordered the change to be made. He then returned to the 37 south shaft to expedite removal of the men there so that the 37 south fan could be stopped.

The division chief electrician was lowered through the downcast compartment of the 13 south shaft in a shaft-sinking bucket, and he rearranged the doors to make the manway compartment a downcast. The normal intake compartment then was covered to force all the air down the manway and clear the stairway of smoke; but the fan, which was installed underground just east of the shaft bottom and was operating blowing, was recirculating some return air from the fire through a crosscut and the pump room. A large part of the recirculation was through the sump, (under the pump room and the air shaft) because when the pump, which was operated by an automatic float switch, lowered the level of water in the sump, passage was provided for return air from the pump room to the fan under the door between the pump room and the stairway. Thus, the air at the shaft bottom was of the same quality as that in the main east entry, and the men in 13 north would have to travel 150 feet through this air to the shaft. Moreover, the recirculated air was being forced through the 13 north section, where the 75 men were waiting.

After all other men from the east workings had been hoisted through the 37 south shaft, it was decided to withdraw the men who had been fighting the fire and stop the 37 south fan, so that all efforts could be directed toward getting the men at the 13 north entry to the surface.

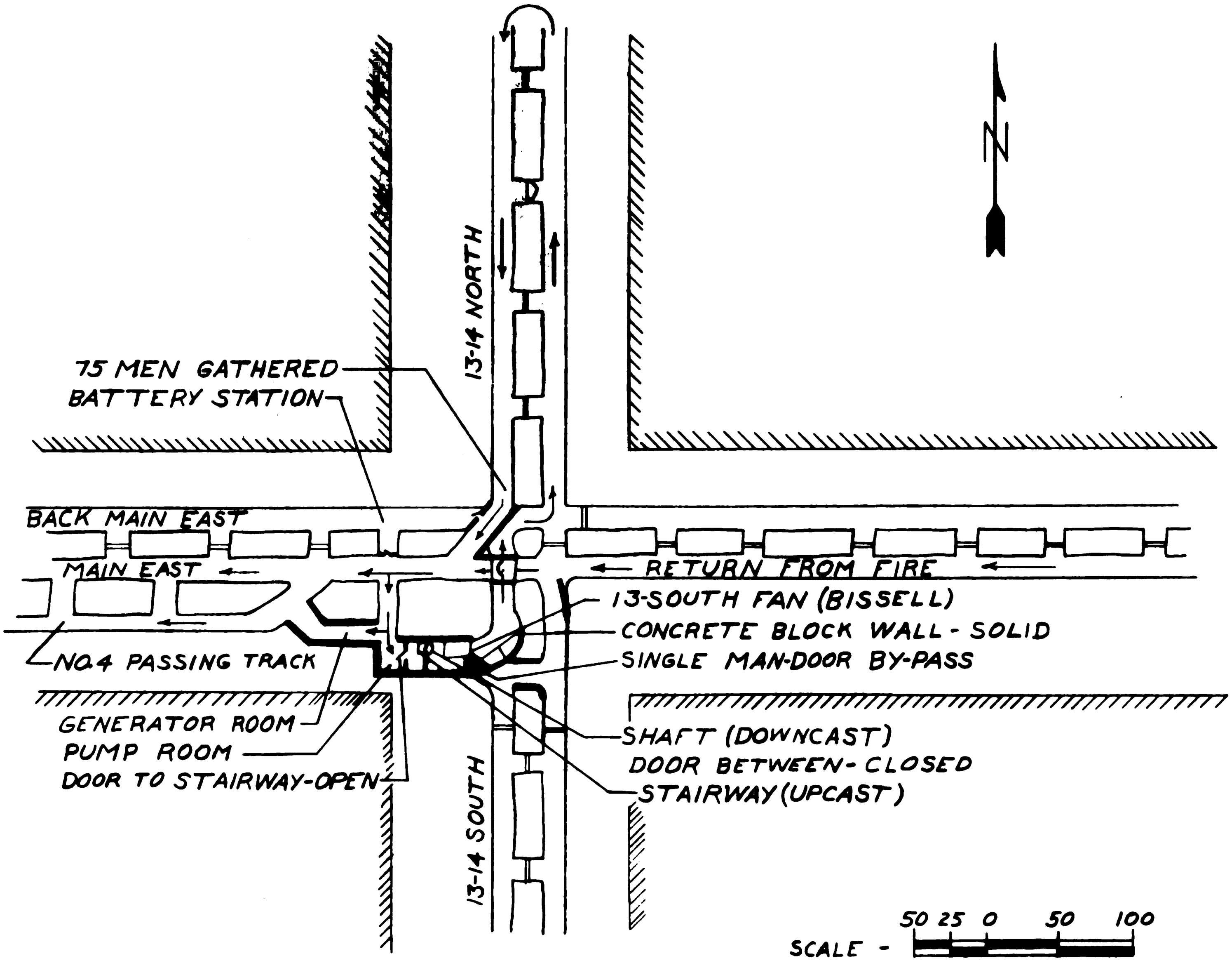

Figure 3. - Details of 13 south (Bissell) shaft bottom.

The men in the 13 north entry were directed across the main east entry to the bottom of the stairway in the 13 south (Bissell) shaft by members of the State mine rescue team and company employees; all were equipped with universal-type gas masks or self-rescuers. Even though the 37 south fan was not operating, smoke from the fire drifted through the main east entry, and a machine cable was rigged across the main east entry through the pump room to the stairway as an extra precaution to guide the men so that they would not miss the opening to the pump room and continue westward in the main east entry or the passing-track entry. They were convoyed to the stairway in small groups by the rescuers.

All the men had been checked out of the mine by 7:30 p.m., and preparations were begun immediately to combat the fire from the west side. The air from the 13 south fan was directed eastward through the fire area and discharged through the 37 south air shaft and the No. 52 (Riverton) shafts. About 9 p.m. it was discovered that the fire had reached a point approximately 750 feet east of the 13 north, indicating that while it was being fought from the east side, the air currents had spread the flames nearly 1,200 feet westward. Considerable heat and smoke was encountered as far west as the 13-north overcast, and undoubtedly stopping the 37 south fan had checked further rapid westward propagation of flame as far as the 13 north entry.

The fire was fought by direct means. Rock dust was applied to the burning shale, timbers, and coal, to cool and extinguish the fire, and the heated material was loaded into mine cars with a loading machine. A layer of rock dust was placed on the floor of each car, and the loaded material was covered with a layer of rock dust. The cars were sprinkled with water, also, before being transported to the shaft bottom. The fire was not serious, and the damage was relatively slight until a point was reached about 1,650 feet east of 13 north, which was 250 feet west of the origin of the fire. At that point the first serious fall was encountered, the fire was more intense, and the roof was working from the effect of the heat. By the end of the second shift on Thursday, August 18, 3 days after the fire had started, the company officials decided that the fire should be sealed. By that time it had been determined that the fire was spreading to timber in the back main east entry.

During the first shift on August 18, a man was killed by a fall of roof caused by dislodgment of timber by haulage equipment. This accident was chargeable indirectly to the fire because the victim was a member of the fire-fighting crew. He was riding in an empty car of a trip being pushed toward the loading machine, when the cars were derailed, dislodging the legs of four cross bars, and the rider was crushed by falling timber and rock.

The two seals on the west side of the fire area were completed on Saturday evening, August 20. The seals were 1,500 feet inby 13 north entry and just east of 15-16 north and south and were constructed of wood plastered with wood fiber. Pipes with valves were fitted into the seals to permit sampling of the atmospheres behind the seals.

After the west seals were completed, the fan at the 37 south (Wentworth) shaft was started, a hole was made in the overcast, 25 north was bratticed off, and a door was placed in the mouth of 37 south. The air was thus directed westward through the main east entry toward the fire, returning through the back main east entry to 38 south, thence to 10 east off 37 south, thence to the shafts of the abandoned No. 52 (Riverton) mine. Considerable work had to be done in removing roof falls and rib "rash" caused by heat while the fire was being fought from the west, so that materials for building the east seals could be transported to the location selected.

While establishing ventilation for the location of the east seals, it was noted that smoke and carbon monoxide cleared quickly, despite the fact that the air current was weak. The stoppings between the two main east entries had long been ignored, because both entries had been return airways and many stoppings had been opened purposely to equalize the pressure caused by moving trips during normal mining operations. It was found that some air traveled westward in both entries, in some instances 1,000 feet beyond an open crosscut, indicating that the air was traveling through the west fire seals or leaking through the seals in the abandoned entries and out the abandoned shafts.

The company officials stated that: (1) all seals in the fire area were believed to be reasonably tight; (2) any workings to the north that had holed into the abandoned Bissell mine had later been closed, and the Bissell mine shafts had been filled; (3) although mine No. 59 had holed into Sangamon No. 2 mine on the south, it was felt that a number of seals between the fire area and the Sangamon mine, together with squeeze conditions in that part of No. 59 mine, precluded any possibility of air movement in that direction, and, therefore (4) any leakage caused by the pressure of the 37 south fan would appear as leakage through the west fire seals or through the south panels along the main east entry, and thence through seals along the west side of 37 south, moving toward the Riverton shafts. The west fire seals and the 37 south seals were examined on Sunday morning, August 21, and no evidence of leakage was found.

The officials knew that carbon dioxide had been used successfully in extinguishing another Illinois mine fire,[2] and they were contemplating flooding the fire area with it. They were informed, however, that unless the carbon dioxide could be confined within the fire area, its effect would be of doubtful value. The officials thought that the seals to the abandoned area were in reasonably good condition and that there would be very little leakage; consequently they decided to use carbon dioxide.

CONDITIONS IMMEDIATELY PRECEDING INTRODUCTION OF CARBON DIOXIDE

While the east seals were being installed, a 2-inch pipe line was laid for 1,700 feet from the pump room at the 13 south air shaft to the west seals and was connected to the 3-inch water-discharge line in the air shaft, the pump being disconnected temporarily.

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[2] Westfield, James, Brumbaugh, H. C., and Whittaker, R. W., Extinguishing Fire with Carbon Dioxide in the Valier Mine, Valier Coal Co., Valier, Ill.: Bureau of Mines Inf. Circ. 7563, 1950, 10 pp.

On August 22, prior to the introduction of the carbon dioxide, samples were taken of the atmosphere in the fire area and sent to the Bureau of Mines laboratory at Pittsburgh, Pa., by airplane. The samples were given special handling there, and the analyses were received by telephone at the mine office about 10:00 p.m. the same day. The analyses are shown in table 1.

TABLE 1. - Analyses of air samples taken prior to the introduction of carbon dioxide

Bottle No.	Location	Percent					
		CO_2	O_2	H_2	CO	CH_4	N_2
3813	West fire seals, back main east.....	10.9	7.4	2.0	1.8	1.0	76.9
4614	West fire seals, back main east.....	10.9	7.4	2.0	1.8	1.0	76.9
6496	West fire seals, main east..........	12.3	5.6	1.7	1.8	1.1	77.5
6896	West fire seals, main east..........	12.2	5.5	1.7	1.7	1.2	77.7

The possibility of an explosion constitutes an ever-present hazard while seals are being constructed and after a fire area has been sealed until the oxygen content of the portion of the atmosphere surrounding the active fire is reduced to less than the critical oxygen value of the air-free original atmosphere. The mathematical method developed by Ash and Felegy[3] of determining whether an atmosphere containing combustible gases is capable of forming an explosive mixture with air was used before the diluent (carbon dioxide) was added. This was done by determining the critical gas-mixture value of the air-free original atmosphere represented by the above samples.

Using sample 3813, the percentage by volume of gases other than air is:

$$K_s = 100 - \frac{(O_2)s\ (100)\ \text{percent}}{20.93}$$

$$= 100 - \frac{7.4\ (100)}{20.93} = 64.65 \text{ percent}$$

The volumes of the individual constituents, air-free, follow:

$$CO_2 = \frac{10.9}{64.65}\ (100) = 16.86 \text{ percent} = \text{symbol } D_1$$

$$H_2 = \frac{2.0}{64.65}\ (100) = 3.09 \text{ percent} = \text{symbol } (H_2)_1$$

$$CO = \frac{1.8}{64.65}\ (100) = 2.78 \text{ percent} = \text{symbol } A_1$$

$$CH_4 = \frac{1.0}{64.65}\ (100) = 1.55 \text{ percent} = \text{symbol } B_1$$

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[3] Ash, S. H. and Felegy, E. W., Analyses of Complex Mixtures of Gases: Bureau of Mines Bull. 471, 1948, 202 pp.

Since carbon monoxide, methane, hydrogen, nitrogen, and carbon dioxide are present in the air-free original atmosphere, and $10.2(H_2)_1 = 10.2 (3.09) = 31.52$ and is greater than D_1, or 16.86, the applicable formula for finding the critical gas mixture value is:

$$C.G.M.V._{N_2} = \frac{10,000}{5.15A_1 + 7B_1 + 17.55(H_2)_1 - 0.6225D_1}$$

$$= \frac{10,000}{5.15\ (2.78) + 7(1.55) + 17.55\ (3.09) - 0.6225\ (16.86)}$$

$$= \frac{10,000}{68.90} = 145 \text{ plus}$$

By inspection, the critical gas-mixture value calculated from the analyses of the other samples would be somewhat greater.

As the critical gas-mixture value is greater than 100, neither the original atmosphere nor the air-free original atmosphere is explosive, and they cannot become explosive regardless of how much air is admixed with them. No further calculations on the explosibility of the atmosphere in the sealed area are necessary.

INTRODUCTION OF CARBON DIOXIDE

At 1:35 a.m., August 23, which was 7-1/2 days after the fire began, a tank truck equipped with a converter to gasify liquid carbon dioxide by heating with liquefied petroleum gas began to feed the carbon dioxide slowly into the sealed area through the pipe line. Gaseous rather than liquid carbon dioxide was used to avoid freezing the line or breaking it because of contracting from extremely low temperature.

A sample was collected from behind the back entry seal of the west seals at 7:30 a.m. August 23, and contained 43.4 percent carbon dioxide and 3.6 percent oxygen. As the gas was introduced through the main entry seal and it was known that the first opening between the entries was 200 feet inby the seals, it was apparent that the carbon dioxide was well-diffused through the western end of the fire area. The pressure at the east seals had remained negative through the night, and all men were removed from that area and the east fan was stopped about 6 a.m. A State mine rescue team and a Federal coal-mine inspector, all wearing oxygen breathing apparatus, closed and plastered the trap doors in the east seals at 3 p.m., August 23. Analysis of a sample collected at the main entry east seal at that time showed: carbon dioxide, 8 percent, and oxygen, 16 percent; this result was discouraging because it indicated that the carbon dioxide had not diffused appreciably throughout the sealed area. This, in addition to the fact that the pressure had remained generally negative at the east side and that the pressure on the back entry east seal was still slightly negative, indicated possible leaks from within the sealed fire area to adjacent sealed abandoned room panels.

Injection of carbon dioxide was continued until 8 a.m., August 24 at which time 21 tons had been used, which, upon expansion to normal atmospheric pressure, would equal a volume well in excess of the calculated volume of the sealed area.

A sample collected at the west fire seals, after pumping of carbon dioxide had ceased, contained 57 percent carbon dioxide and 6 percent oxygen. The seals were allowed to remain undisturbed until August 30, with both fans stopped except for short periods during sampling. Meanwhile, samples were collected from the sealed area, but it was never possible to obtain a representative sample from the east seals, because they were under negative pressure continuously. By manipulating the fans, it was sometimes possible to establish positive pressure at the east seals, but samples taken under such conditions gave no significant information. The barometoric pressure remained generally high during this period. At times the west seals were under positive pressure with the fan operating, but at other times they were under positive pressure only when the fan was stopped. The samples collected at the west seals on August 28 showed considerable dilution of the carbon dioxide concentration, and as weather forecasts indicated little likelihood of a falling barometer, it was decided to open the seals before the carbon dioxide should be entirely dissipated by leakage into old workings and by dilution with fresh air.

Analyses of air samples taken during the fire are shown in table 2.

RECOVERING THE FIRE AREA

Air-lock doors were built in the main east haulage road just west of 13 north entry. A hole was opened in the wall at the 13 south (Bissell) fan, and the air was directed toward the west seals through the main east haulage road, returning through the back east entry to 14 north entry. Another split was directed from the fan into the 14 north, and all the air returned through 13 north to the main east and thence to the main bottom. This coursing of the air permitted the fire-fighting crews to advance with the intake air, but it also subjected the haulage-men, generator attendants, and bottom men, who were outside the door at 13 north, to noxious gases in the return air. However, no other arrangement was feasible. After some experimentation with splitting of the air current, enough air was provided in the main return to maintain the carbon-monoxide content at all times below 0.01 percent, and usually below 0.005 percent.

The seals were opened at 12:10 p.m., August 30, which was 6 days after introducing carbon dioxide and sealing, whereupon the loading of the caved material and retimbering of the affected area were resumed immediately. The mine was restored to normal operation on November 14, 3 months after the fire occurred. The fire had started at what was possibly the worst point in the mine with respect to adverse roof conditions. From the point where the fire originated, I-beams were installed on centers not over 4 feet apart for distances of 200 feet eastward and 400 feet westward, and they were lagged extensively. Farther westward, the haulageway was timbered, though somewhat less heavily, with rail bars, wooden cross bars, occasional I-beams, and props. The timber legs and lagging provided abundant fuel for rapid spread of the fire. As a consequence of the heat and the burning out of timbers, the soapstone and horsebacks of the roof caved badly, which made fire-fighting and retimbering difficult and dangerous. Retimbering consumed most of the time required to complete recovery work.

TABLE 2. - Analyses of air samples

Bottle No.	Location	Date	Hour	CO_2	O_2	H_2	CO	CH_4	N_2	Remarks
2292	Return top No. 52 air shaft	8/20	7:57 p.	1.78	15.82	0.00	0.18	0.40	81.82	Before sealing.
9299	Return top No. 52 hoist shaft	8/20	8:30 p.	1.81	16.29	0.00	0.17	0.40	81.33	Do.
9179	Back entry west seal	8/23	1:25 a.	11.7	6.8	1.7	1.8	0.7	77.3	Before adding CO_2.
9679	Duplicate of 9179	8/23	-	11.5	7.0	1.6	1.8	0.7	77.4	Do.
5715	Back entry west seal	8/23	7:20 a.	45.9	3.4	1.2	1.1	0.6	47.8	CO_2 flowing 6 hours.
5675	Main entry outby west seal	8/23	7:30 a.	0.52	20.65	0.00	trace	0.0	78.82	Do.
3213	Main entry east seal	8/23	4:30 a.	0.06	20.85	0.00	0.00	0.00	79.09	Negative.
3813	Main entry east seal	8/23	3:00 p.	7.92	15.26	0.14	0.64	0.25	75.79	App. crew plastered man-doors.
7178	Back entry east seal	8/23	2:55 p.	0.67	19.84	0.00	0.09	0.04	76.36	Do.
6296	Back entry west seal	8/23	6:10 p.	50.2	6.5	0.4	0.7	0.4	41.8	CO_2 added for 16 hours.
6336	Duplicate 6296	-	-	50.2	6.5	0.5	0.5	0.4	41.9	
6716	Back entry west seal	8/24	1:20 p.	9.33	18.18	0.00	0.04	0.11	72.34	Spoiled when taking.
5755	Back entry west seal	8/24	1:25 p.	56.6	6.0	0.3	0.4	0.4	36.3	
1732	Main entry east seal	8/25	10:40 a.	4.11	16.38	0.00	0.11	0.24	79.16	Positive, short time.
7828	Back entry east seal	8/25	10:35 a.	1.47	17.54	0.00	0.04	0.18	80.77	Do.
5955	Main entry west seal	8/27	9:30 a.	31.4	4.1	0.0	0.12	0.6	63.78	Fan stopped; negative when running.
6456	Back entry west seal	8/27	9:40 a.	40.8	4.6	0.0	0.5	0.5	53.6	Do.
6376	Main entry west seal	8/27	2:55 p.	35.2	1.2	0.0	0.13	0.6	62.87	Fan running.
6496	Back entry west seal	8/27	3:15 p.	38.4	5.5	0.0	0.19	0.5	55.41	Do.
6756	Main entry west seal	8/28	9:20 a.	27.4	3.7	0.0	0.09	0.6	68.21	Fan stopped; negative when running.
5915	Back entry west seal	8/28	9:30 a.	35.5	4.2	0.0	0.14	0.5	59.66	Do.
7908	Back entry west seal	8/30	6:30 p.	6.6	13.9	0.00	0.18	0.1	79.22	200 feet inside seal.
1162	Back entry west seal	8/30	1:30 p.	1.33	20.38	0.00	Pos. trace	0.02	78.37	Return, fire area 3,200 c.f.m.
6496	Back entry west seal	8/30	9:30 p.	0.70	20.11	0.00	0.03	0.00	79.16	Do. 4,100 c.f.m.
6216	Back entry west seal	8/31	2:30 a.	1.09	19.75	0.00	.07	0.07	79,02	Do. 4,000 c.f.m.
3994	Back entry return at west seal	8/31	9:15 a.	1.32	19.41	-	0.10	0.11	79.06	Do. 5,600 c.f.m.

TABLE 2. - Analyses of air samples (Continued)

Bottle No.	Location	Date	Hour	CO_2	O_2	H_2	CO	CH_4	N_2	Remarks
7178	Back entry west seal	8/31	1:00 p.	1.45	19.29	-	0.11	0.14	79.01	Return, fire area 5,500 c.f.m.
3124	Back entry west seal	8/31	9:00 p.	0.34	20.58	-	0.04	0.10	78.94	Do. 4,600 c.f.m.
6876	Back entry west seal	9/1	3:00 a.	0.13	20.90	-	trace	0.04	78.93	Do. 6,000 c.f.m.
3144	Top Sangamon air shaft	9/6	6:30 p.	6.61	3.70	-	Pos. trace	0.38	89.31	Suspected return of fire.
5116	Top Wentworth shaft	9/6	5:30 p.	6.06	6.24	0.42	0.56	0.72	86.00	
3904	"Face" main entry west side	9/7	5:27 p.	0.05	20.79	-	trace	0.00	79.16	Taken while timbering
7778	Top Wentworth shaft	9/8	9:15 a.	0.16	20.81	-	trace	0.00	79.13	Pressure reversing.
5795	Top No. 52 main shaft	9/27	1:30 p.	3.64	10.38	-	0.00	0.99	84.99	
395-A	Near top No. 2 air shaft	9/27	2:30 p.	5.03	8.10	-	0.00	0.36	86.51	
9799	Top No. 2 air shaft	10/9	7:50 a.	5.04	6.96	-	trace	0.25	87.75	
9459	Between 18 S. and 19 S. inside fire seals.	10/15	8:45 a.	2.24	17.81	-	0.08	0.09	79.78	Taken by app. crew.

To load out the debris required the cleaning of 6,000 linear feet; this consisted of partly burned timber legs, twisted I-beams, the frames of four mine cars, and, chiefly, huge quantities of fallen roof rock. Of that total distance, 4,300 feet in the haulage entry, mostly east of the fire zone proper, was affected by heat but not by direct contact with fire; caving was not excessive, and only moderate retimbering was necessary. An additional 900 feet, both within and west of the sealed area, was affected slightly by fire and heat, but the remaining distance, 750 feet, was rehabilitated with great difficulty. This 750 feet consisted of 350 feet in the haulage entry, 150 feet in the back entry, together with several crosscuts and the entrances to 17 south and 18 north entries.

In this severely affected area the roof had caved to heights ranging from 20 to 60 feet and widths of 14 to 18 feet, and greater at crosscuts. The following method of retimbering was followed: Crossbars, consisting of 100- to 120-pound rails, were set on vertical legs on 8-foot centers; the legs were cut from timber 6 to 8 inches in diameter and were either full-round or planed on two sides. The span between two adjacent rail bars was covered with four layers of flat wooden bars, in the form of a crib, on 18-inch centers; and the set was then cribbed to the roof with round props. Later, a rail bar, set on vertical legs, was placed at an intermediate point between two other rail bars to reduce the 8-foot span by half. The cribbing was interlaced from crib to crib and from set to set.

On September 28, one man was killed and eight were injured badly enough from a fall of rib to require hospital treatment. One of the injured sustained several fractured ribs, and the others suffered bruises and lacerations. Virtually the entire crew, reported as 23 men, was erecting timber when the fall occurred, and it was miraculous that a major disaster was averted. A piece of rock 20 feet long, 4 feet wide, and 5 feet high "slabbed off" from about 25 feet above the entry floor and rolled on to the cribbing under construction, collapsing that set and three others and resulting in a large fall of cribbing and rock. Two men were trapped; one was released with the aid of a hydraulic jack, but the other was injured fatally and found crushed between a large piece of rock and the cribbing. Seventeen hours were required to extricate the body.

For several days after the seals were opened, progress was rapid, because neither fire, heat, nor much fallen material was encountered. The badly caved area was reached quickly, and fire was discovered along the ribs, spotty at first, but increasing in severity and extent as the work progressed. At times in the main entry, and almost continuously in the back entry, the mass of glowing material extended from rib to rib and as high as 10 feet from the floor. Very little burning coal was handled, but the shale, cap rock, and soapstone was red- to white-hot, appearing translucent at times. Sometimes the heat became so intense that it was necessary to bank the whole "face" with rock dust between loading each two cars to suppress the heat and gases.

The wooden floors of the mine cars were covered heavily with rock dust, and the hot material was smothered with rock dust before, during, and after loading into cars, which then were hauled to the shaft bottom promptly. At times it was necessary to water each loaded car, and rush it to the shaft bottom as soon as it was loaded. The rock dust was dumped directly from the sacks or shoveled by hand, and a rock-dust distributor also was used to some extent with good effect. Under the most severe conditions, 40 to 50 tons of rock dust were used in one day; sometimes as much was used in one shift, because at such times the ratio was two shifts timbering to one shift loading. Without adequate supplies of rock dust, it would have been impossible to carry on the work.

Ordinarily, carbon monoxide was not encountered in any harmful concentration, but sulfur dioxide was given off in irritating quantities when very hot material was handled. To clear the smoke and gases and to reduce excessive heat, especially when timbering, two auxiliary fans with tubing were installed. One fan was operated blowing and one exhausting, and this auxiliary ventilation was quite helpful.

Very little indication of the large volume of inert gas that had been added was found in the sealed area after unsealing and during subsequent recovery work, but carbon monoxide was detected at adjacent abandoned shafts. When the 17 south and the 18 north seals were uncovered, it was found that they were badly damaged, which accounted for the escape of the added carbon dioxide from the fire area.

Some idea of the magnitude and direct cost of the job of restoring the mine can be gained from considering the number of men and officials employed for 3 months and the material used. An average of 30 men was employed on each of the three shifts per day, 7 days per week.

Following is a partial list of the material used:

56,276 fifty-pound sacks, or 1,407 tons, of rock dust.
147 steel rail bars, 100- to 120-pound; lengths to 24 feet.
179 wooden bars (flat), 16 feet long, 5 x 6 inches minimum cross section.
1,306 wooden bars (flat), 12 feet long, 5 x 6 inches minimum cross section.
1,606 wooden bars (flat), 10 feet long, 5 x 6 inches minimum cross section.
467 round props, 14 feet long, 6 inches minimum diameter.
6,629 round props, 8 feet long, 4 inches minimum diameter.
14,155 round props, 6 feet long, 4 inches minimum diameter.
97 planks, 2 x 6 inches x 16 feet.
855 planks, 2 x 8 inches x 16 feet.

The seal necessary to reseal the 17 south entry and the angle entry was 32 feet wide at the base and 46 feet, 5 inches high at the highest point; it was built of solid concrete blocks, 8 x 8 x 16 inches, 5 blocks thick, and approximately 5,000 blocks were required.

A total of 7,258 cars averaging 2-1/2 tons of rock per car were hoisted, and many additional tons of material, which was not hot, were "gobbed." Obviously, many other items of cost, direct and indirect, are not listed.

INVESTIGATION OF CAUSE OF FIRE

All of the events concerning the collision and the resulting short circuit are known, and the investigation of the cause resolves into a summary and analysis of direct and indirect factors.

The collision occurred because there was no definite system of checking the trips at the passing track. When the wrecked cars became entangled in the power wires, which caused the short circuit, the circuit breakers did not cut out all the generators from the line. The circuit breakers on some of the generators did not open, because they were too far from the short circuit, and the respective currents drawn through them did not exceed the settings of the over-current tripping devices. Table 3 shows the distances involved.

TABLE 3. - Distances from the wreck to the respective circuit breakers, showing the effect of the short circuit

Substation	Distance, in feet, between wreck and substation	Position of breaker
Main east at 13 south..............	2,000	Open
37 south...........................	8,400	Open
13 north...........................	8,000	Closed
25 north...........................	9,200	Closed
Surface............................	10,700	Closed

The breaker on the 37 south generator opened, even though it was slightly farther from the fault than the 13 north substation, because the 37 south motor-generator set was continuously carrying a near-capacity face load, and a small additional current was enough to open its breaker. The breaker at the 25 north substation did not open, even after the other sets were off the line. Assuming that line resistance per foot was approximately the same in all parts of the system because of a similar arrangement of conductors, indications are that distance from the point of short circuit was the principal factor determining whether a particular circuit breaker opened or remained closed. Lack of sectionalization of the electrical distribution system was the cause of sustaining the short circuit and starting the fire.

CONCLUSIONS

1. An old saying is worth repeating, - it is easier to prevent a fire than to extinguish it. As a great many fires in present-day highly mechanized mines are of electric origin, a very small part of the cost of fighting a serious fire would provide adequate protective equipment to prevent one.

2. Carbon dioxide introduced into a sealed area can extinguish a fire quickly, provided that the carbon dioxide can be retained in the area. This was proved in another recent mine fire in Illinois.[4] In the present instance the use of carbon dioxide was not completely successful because gas was not retained in the sealed area, but leaked through seals into abandoned areas. It is thought, however, that the carbon dioxide cooled the area sufficiently to permit its prompt re-opening without immediate rekindling of the fire. Falls in the sealed area were high and compact at many points, and it is doubtful whether the carbon dioxide gas penetrated this caved material; however, if the gas had been retained, the cooling effect would have been increased greatly. This was attested by the lack of fire and heat near the west seals, where it is known, from the samples of the atmosphere, that the concentrations of carbon dioxide remained high for at least several days.

3. The use of water would have been inadvisable because of its effect upon the roof and rib and because of the possible generation of dangerous quantities of hydrogen and carbon monoxide from water in contact with highly heated material. The fire could not have been loaded out without the use of rock dust to smother the heated material in the wooden mine cars and to bank the heated material before loading.

4. An extremely hot fire can be loaded out by using a loading machine and applying rock dust. In the absence of explosive gas, the quantity of burning material is unimportant, the principal time-consuming factor being the amount of retimbering required.

5. The remedy for nearly all electrical fires is protection against overcurrent and overheating. It is not possible to anticipate every condition that may arise. High-resistance short circuits and other line faults involving high resistance, which may not cause the circuit breakers to open, can exist. Nevertheless, with proper planning it is possible to sectionalize the distribution system and to provide overcurrent protection that will protect against the faults most likely to occur.

6. Although many potential sources of electrical fires other than trolley-haulage mishaps exist in mines, any measures that will minimize the chances of derailments are worthy of consideration.

7. Two separate openings accessible to all active sections should be a minimum requirement for every mine. In maintaining two escapeways from each working section, it is advisable that access to the surface be available at all times without requiring the changing of doors or other ventilating appliances and without rigging any special apparatus. The desirability of one or more additional openings near active sections in extensive mines is attested by the escape of 163 men through a new air shaft to No. 59 mine.

8. It also is advisable that plans for procedure in event of any emergency be established before emergencies arise, and that every mine official, and preferably every employee, be thoroughly familiar with the part of such procedure that affects him and his working environment.

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[4] See footnote 2/.